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Bronchitis-like symptoms and proximity air pollution in French elderly

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Dispersion model

Summary
Background: Our aim was to explore the association between respiratory health and proximity air quality in elderly.
Methods: The prevalence of respiratory conditions was linked in 2104 individuals aged ≥65 years recruited in Bordeaux (3C Study) to home address concentrations of NO_2, CO, SO_2, fine particles (PM_{10}), VOCs and benzene, estimated through a dispersion model combining data on background air pollution, traffic characteristics, and conditions of topographical and meteorological dispersion of air pollutants.
Results: Mean [minimum; maximum] values of the annual concentrations ($\mu g/m^3$) of proximity air pollutants were respectively: 28 [18; 72.2] for NO_2, 420 [350; 1337] for CO, 7.5[5; 13.7] for SO_2, 23.1 [19; 51] for PM_{10}, 8.1 [0.01; 116.6] for VOCs and 1.8 [1.5; 6.9] for benzene. Using a binary logistic regression model, PM_{10} were significantly associated with usual cough (Odds-Ratio = 1.33 (95% confidence interval: 1.00—1.77) for exposed compared to non-exposed) and SO_2 with usual cough (1.55 (1.16—2.08)) and phlegm (1.45 (1.04—2.01)). We found a 10% and a 23% increase in usual cough for a 10 $\mu g/m^3$ increment in PM_{10} and a 1 $\mu g/m^3$ increment in SO_2 respectively, and a 23% increase in usual phlegm for a 1 $\mu g/m^3$ increase in SO_2. A sensitivity analysis showed similar results when considering 3-year proximity pollution. A more pronounced effect of SO_2 and PM_{10} on usual cough and phlegm was observed in woman.

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Conclusions: Our assessment of exposure to proximity air pollution has shown an increased prevalence of bronchitis-like symptoms in elderly living in areas polluted by SO_2 and PM_{10}.

Introduction

The increase in the number of elderly worldwide[1] and the occurrence of almost inevitable chronic diseases at older ages conduce to better investigate and understand the health consequences of exposure to various risk factors, including environmental risk factors such as air pollution.

Overall effects of urban air pollution on the health begin to be well established, with several studies having reported significant relationships of short-term and long-term exposure to various air pollutants on respiratory morbidity and mortality in children and adults.[2,3] The cardio-respiratory system is the most affected. However, effects among the elderly are still poorly known, with the exception of findings for short-term effects[4–9] indicating a greater impact of air pollution in terms of overall and cardio-respiratory mortality and hospital admissions in elderly than in younger individuals and thus a greater fragility of elderly to air pollution.

Assessment of exposure to air pollution constitutes a major issue in the investigation of health effects of air pollution. All the studies reporting short-term effects of air pollution in elderly have considered exposure to background air pollution, which is only a proxy of the real exposure of the individuals. So far, no study has estimated the exposure to air pollution at the proximity level in a population of elderly, in order to reduce exposure misclassification.

This paper has two objectives: (1) to describe exposure to proximity air pollution in individuals aged over 65 years for whom few exposure data are available (2) to investigate the association between exposure to these pollutants and respiratory health in order to provide more information on air pollution effects in elderly. To this extent, our study investigated the respiratory health status of elderly in relation to outdoor air quality at the proximity of their residence address as assessed by the estimation of levels of major urban air pollutants (namely nitrogen dioxide (NO_2), carbon monoxide (CO), sulphur dioxide (SO_2), suspended particulates of aerodynamic diameter less than 10 μm (PM_{10}), volatile organic compounds (VOCs) and benzene) using a dispersion model. The study was carried out in a large population-based sample of elderly individuals living in the Bordeaux agglomeration, France. Potential confounders of the association between air pollution and respiratory health were taken into account.

Methods

The 3C study and the sample

Data were drawn from the 3C (3 Cities) study,[10] in which a cohort of subjects aged 65 years and over has been enrolled in three cities in France (Bordeaux ($N = 2104$), Dijon ($N = 4931$) and Montpellier ($N = 2259$)) and followed-up in time with the aim of investigating the development of vascular illness and dementia. At the beginning of the survey, the individuals were not institutionalised according to exclusion criteria of the 3C Study. The relationships between air pollution and respiratory health presented here refer to data of the first baseline cross-sectional study that took place between 1999 and 2001. The population used in this article is composed of the 2104 individuals aged 65 years and over living in the agglomeration of Bordeaux (''Communeauté Urbaine de Bordeaux'' (CUB)) in SE France, namely in the six administrative areas of Bordeaux, Pessac, Talence, Mérignac, Floirac and Lormont.

Participants were recruited on the basis of the electoral list of the Bordeaux agglomeration. In France, there is a satisfactory participation of the elderly to the elections (up to 80% according to age class). Those eligible should have been aged 65 years and over, registered on electoral rolls, non-institutionalised and not intending to move within four years from the beginning of the survey. Study design and sample baseline characteristics have already been reported elsewhere.[10] The study protocol was approved by the Ethical Committee of the University Hospital of Kremlin-Bicêtre. Written informed consent and access authorization to medical record were obtained from each participant.

Data were gathered during an interview in face to face led by specially trained investigators with a standardised administered questionnaire including items about the respiratory health derived from the European Commission Respiratory Health Study (ECRHS) (www.ecrhs.org), and potential risk factors such as socio-demographics features, education and socio-economic status, occupations during life, tobacco and alcohol consumption, and eating habits (frequency questionnaire). Successively, the 2104 elderly participated in a health check-up conducted by a doctor. The data presented in the present paper concern responses to the standardised questionnaire and Body Mass Index (BMI) through weight and height assessed during the health check-up.

Proximity air pollution using a dispersion model

To estimate exposure to traffic-related air pollution of the individuals at the proximity level of their dwelling a dispersion model implemented by the software STREET 5 combining data from background air pollution, traffic characteristics, and conditions of topographical and meteorological dispersion of air pollutants was used.[11] More specifically, STREET integrates two databases: a database of air pollution emission factors calculated from the IMPACT 2 software developed by the French Agency of Environment and Energy Management (ADEME)[12] and a database of standard air pollution concentrations calculated by the software dispersion WinMISKAM[13] (Fig. 1). This model

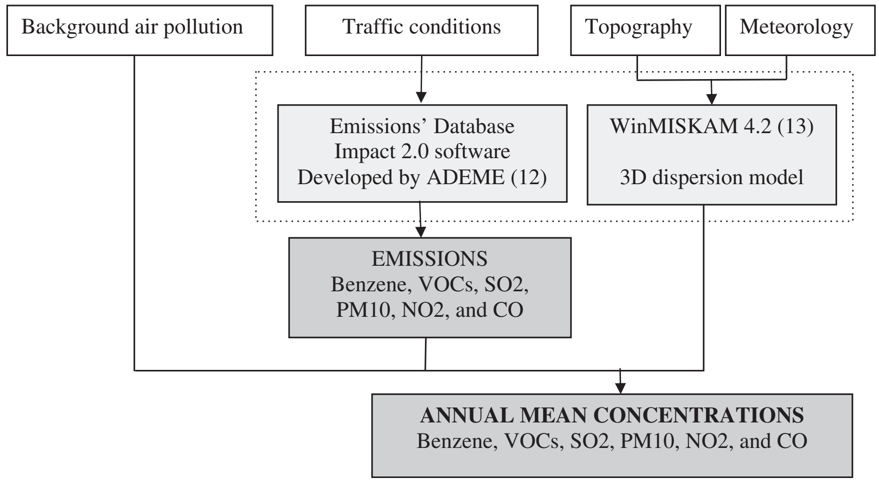

Figure 1 Description of the STREET 5 software.[14]

provided the annual average concentrations of benzene, VOCs, CO, NO_2, SO_2 and PM_{10} at the individuals' addresses for the period of the survey. It was validated in 2005 by Pénard-Morand[14] of our team in order to avoid exposure misclassification in the study of the relationship between exposure to proximity air pollution and respiratory and allergic health in children of the 6 French Cities among which the city of Bordeaux. The model is also largely routinely employed in France by several Air Quality Monitoring Networks.

Background air pollution

There are 4 stations measuring background air pollution in the Bordeaux agglomeration: Grand Park, Talence, Bassens and Floirac. They publish every year annual average concentrations for nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and particulate matter of aerodiameter <10 m (PM_{10}). In order to attribute representative background air pollution values at each individual, the addresses of the 2104 subjects and the 4 fixed stations measuring background air pollution were geo-coded on a plane provided by the National Geographic Institute (IGN). With the help of the Air Quality Monitoring Networks in Aquitaine (AIRAQ), the stations that were the most representative were then selected. Annual average of background concentrations of CO and benzene that were not yet available between 1999 and 2001 were added in the model by taking into account the values recommended by AIRAQ, namely 350 $\mu g/m^3$ and 1.5 $\mu g/m^3$ respectively.

Traffic conditions

This is the annual average number of daily vehicles, commercial vehicles, heavy transport, and motorcycle. The average daily traffic in vehicles is defined by the average number of vehicles over 24 h, as determined by counting traffic. The urban community of Bordeaux (CUB) provided data counts on vehicles circulating in the streets from 1999 to 2001. In the case of missing data, we charged as agreed with the CUB the software STREET values with 20,000 vehicles for 24 h on a main street with two lanes and 30,000 vehicles on 24 h for a four-lane street. Regarding the percentage of heavy transport and commercial vehicles, the CUB provided us with a file containing the counting of the main trucks in the Bordeaux region. In the case of missing data, the percentage of 5 and 8% we were advised respectively. For bus and motorcycle, in the case of missing data, the CUB provided the percentages of 0.8 and 1.5%, which were recorded in the software.

Topography and meteorological conditions

For each section of street, STREET lists 98 configurations according to the following parameters: road type (street segment, T junction, 4-way crossroad), number of traffic lanes, situation of buildings (no building, buildings on one side only, buildings on both sides), ratio of the height of buildings to the width of the roadway and width between buildings and traffic lanes. All these data were available on different websites collecting national data. Moreover, direction of the street in relation to the north and slope of the street were recorded. We then geo-coded the addresses of participants and established a Geographic Information System (GIS) map under ''ArcGis 9.2'' to accurately describe all these elements using the topographic database (BD TOPO) of the French National Geographic Institute (IGN). The meteorological data needed were: the direction and speed of wind and the percentage of days with rainfall greater. These data were obtained from the French Meteorology Agency (Météo France).

Respiratory health outcomes

Outcomes considered in the analysis included the following respiratory symptoms and diseases: past year wheezing as defined by ''wheezing and whistling in the chest during the past 12 months'', past year breathlessness at night as defined by ''woken in the night by breathlessness during the past 12 months'', usual dyspnoea as defined by ''usual dyspnoea during day life activities (walking with people of the same age, toilet...) and rest'', and usual cough and phlegm. Lastly lifetime asthma was defined on the basis of the question ''Have you ever had asthma attacks?''.

Other factors considered were age, sex, tobacco smoking habit, socio-economic status defined by household monthly income, weight, BMI as defined by the formula weight/height $\times$ height (kg/m^2) and heart failure. Tobacco smoking habits included smoking at the time of the survey, ex-smoking (having stopped smoking for at least six months) and non-smoking.

Statistical analysis

The annual average concentrations of benzene, VOCs, CO, NO_2, SO_2 and PM_{10} to which the 2104 participants were exposed at the proximity of their house were calculated using the dispersion model previously described for the years 1999, 2000 and 2001 respectively. To calculate the concentrations of VOCs, STREET does not need background pollution of these pollutants. Due to the absence of station recording benzene and CO, the values of 1.5 and 350 μg/m^3 respectively were recorded for these pollutants for the three years. STREET calculates through an algorithm as indicated above. Background air pollution for the same years was also recorded. For each subject we attributed the mean pollutant concentration of the year of the survey.

The prevalence of respiratory conditions was expressed as a percentage of positive responses to the corresponding questions. All the other variables were initially described in terms of mean (quantitative variables) or percentages (qualitative variables) and presented according to sex. The correlations between the proximity air pollutants concentrations were estimated using the correlation coefficient of Pearson and their statistical significance was analysed. To assess the associations between exposure to each air pollutant at the proximity level and health outcomes, the exposure was classified as (1) a categorical variable, namely 'low' vs. 'high' exposure, the latter being defined with respect to the third quartile value of the distribution of the evaluated concentrations at home address for each pollutant and (2) a continuous variable according to the level of the pollutant in μg/m^3 units. The prevalence of health outcomes was calculated in each category of exposure, and unadjusted odds ratios (OR) with 95% confidence intervals (95% CI) were calculated and the associated probability estimated using χ^2 analysis. Successively, multiple binary logistic regression analysis was performed to estimate the OR with 95% CI for the relation of exposure to each pollutant to each respiratory outcome adjusted for potential confounders (aOR) using both the categorical and the continuous variable. Confounders taken into account were: age, sex, smoking, income of household, level of education, occupation, body mass index (BMI) and heart failure. Analyses were conducted by assigning to each subject the estimation of the mean exposure to air pollution in the year in which he/she had participated in the survey. An analysis stratified on sex was also made on the overall population in order to quantify the effects of pollution in each subgroup. Analyses were performed with SAS software version 9.1 (PROC LOGISTIC, PROC GENMOD). Furthermore, a sensitivity analysis was conducted in the sub-sample of individuals seen in 2000 and 2001 by taking into account 3-year and 2-year mean exposure to proximity air pollution in order to consider long-term pollution.

Results

Participants and characteristics of population

Two thousand one hundred and four individuals were seen in Bordeaux. Five hundred seventy four persons were seen in 1999, 1380 in 2000 and 150 in 2001 respectively corresponding to a participation rate of 40% among the eligible persons. The study population was aged on average 75 years with 61% of women and an average weight of 68 kg and BMI of 26 kg/m^2. The salary of the household during the investigation period was: 10% had less than 800 € per month against 34% between 800 and 1500 €, 23% between 1500 and 2300 € and 26% more than 2300 €. 5.4% of participants smoked at the time of the survey or had stopped less than 6 months before, 30% had stopped smoking for at least 6 months (ex-smokers) and 64% of the participants reported that they were not current smokers. Regarding respiratory

Table 1 Participants' social and health characteristics.

	All ($N = 2{,}104$)	Women ($N = 1{,}287$)	Men ($N = 816$)
Demographic			
Women (%)	61		
Age (years) (m $\pm$ STD)[a]	75 ± 5.1	74 ± 5.1	74 ± 5.1
Weight (kg) (m $\pm$ STD)[a]	68 ± 13	62 ± 12	76 ± 11
BMI (kg/m^2) (m $\pm$ STD)[a]	26 ± 4.2	26 ± 4.6	26 ± 3.4
Current household income			
<800 € (%)	10	14	3
800–1500 € (%)	34	40	24
1500–2300 € (%)	23	19	29
≥2300 € (%)	26	19	35
Smoking status			
Never smoked (%)	64	83	33
Stopped since 6 months (ex-smokers) (%)	30	12	58
Smoke actually or stopped since less than 6 months (%)	5	4	7
Health status			
Past year breathlessness (%)	2.5	2	3
Past year wheeze (%)	6	6	7
Past year dyspnoea (%)	14	16	10
Usual cough (%)	11	10	13
Usual phlegm (%)	9	6	13
Ever asthma (%)	7	9	6

BMI = body mass index.
[a] Mean $\pm$ standard deviation.

health, usual dyspnoea was the most frequently symptom reported with a prevalence of 14%. Eleven percent of participants had usual cough, 9% had usual sputum, 7% had suffered from asthma, 6% had past year wheezing, 3% had past year breathlessness and 7% had heart failure. Characteristics, smoking and respiratory health status of participants are shown in Table 1.

Background and proximity air pollution

The distribution of the annual concentrations of air pollutants at the background level and at proximity of the participants' homes according to the dispersion model during the three years of the survey are shown in Figs. 2 and 3 respectively. The averaged concentrations of background pollution ranged from 19 to 21.5 $\mu g/m^3$ for PM_{10}, 18 to 28 $\mu g/m^3$ for NO_2 and 4 to 9 $\mu g/m^3$ for SO_2 and were put at the values of 1.5 and 350 $\mu g/m^3$ for benzene and CO respectively due to the absence of stations recording them. Air pollution concentrations at proximity were higher as averaged proximity concentrations ranged from 19.00 to 51.00 $\mu g/m^3$ for PM_{10}, from 18 to 72.20 $\mu g/m^3$ for NO_2, from 5 to 13.70 $\mu g/m^3$ for SO_2, from 1.50 to 6.95 $\mu g/m^3$ for benzene, from 0.01 to 116 $\mu g/m^3$ for VOCs and from 350 to 1337 $\mu g/m^3$ for CO. These levels varied among the zones, with higher values in downtown Bordeaux. As expected, annual concentrations of proximity air pollutant were strongly correlated each other (Table 4).

Associations between respiratory health status and environmental exposures

The adjusted associations between exposure to air pollution (categorical variable) and respiratory health outcomes

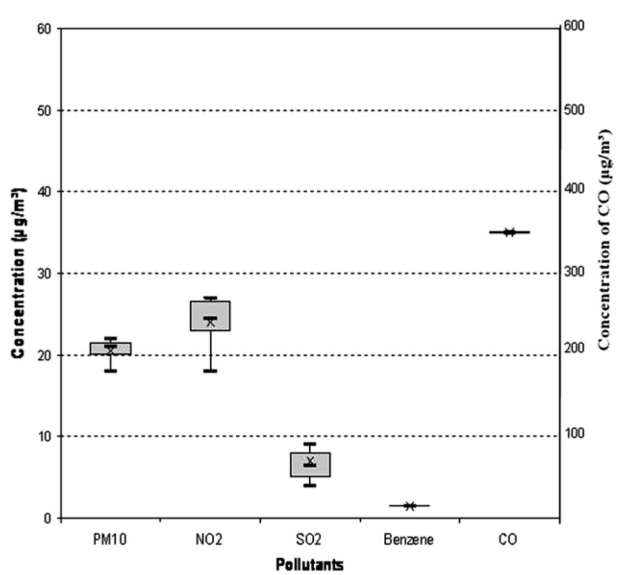

Figure 2 Distribution of background air pollution. Air pollution levels (in mg/m^3) based on three year average of daily measurements (1999—2001). Box plots (fifth percentile, first quartile, Mean, median, third quartile, ninety-fifth percentile). PM_{10}, suspended particulates of aerodynamic diameter less than 10 μm; NO_2, nitrogen dioxide; SO_2, sulphur dioxide; VOCs, volatile organic compounds; Benzene; CO, carbon monoxide.

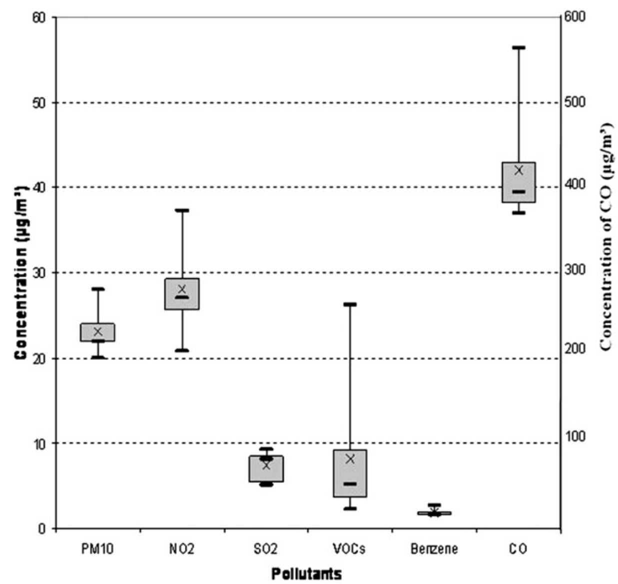

Figure 3 Distribution of proximity air pollutants calculated by STREET 5. Air pollution levels (in mg/m^3) based on three year average of daily measurements (1999—2001). Box plots (fifth percentile, first quartile, Mean, median, third quartile, ninety-fifth percentile). PM_{10}, suspended particulates of aerodynamic diameter less than 10 μm; NO_2, nitrogen dioxide; SO_2, sulphur dioxide; VOCs, volatile organic compounds; Benzene; CO, carbon monoxide.

are presented in Table 2. Exposure to high levels of PM_{10} was significantly associated with usual cough (odds ratio (95% Confidence Interval), OR = 1.33 (1.00—1.77)) and that to high levels of SO_2 with usual cough and phlegm (OR = 1.55 (1.16—2.08) and 1.45 (1.04—2.01) respectively). Both associations between breathlessness at night and SO_2 and between cough and NO_2 were of borderline significance (OR = 1.64 (0.91—2.96) and OR = 1.30 (0.96—1.75) respectively). Benzene, VOCs and CO levels were not related to respiratory health status in this study. Results were confirmed although not always significantly when a continuous variable was considered for expressing air pollution exposure. PM_{10} were associated with usual cough (OR = 1.01 (0.96—1.06) corresponding to an OR = 1.10 for a 10 $\mu g/m^3$ increase in particles) and SO_2 with usual cough and phlegm (1.23 (1.11—1.36) and 1.24 (1.10—1.39) corresponding to ORs = 1.23 and 1.24 for a 1 $\mu g/m^3$ increase in SO_2 respectively). The association between cough and NO_2 was still of borderline significance (OR = 1.01 (0.99—1.04)) corresponding to an OR = 1.10 for a 10 $\mu g/m^3$ increase in NO_2. A borderline significance was observed also between phlegm and NO_2 (OR = 1.01 (0.98—1.04) corresponding to an OR = 1.10 for a 10 $\mu g/m^3$ in NO_2).

Stratification by gender revealed (Table 3) a more pronounced effect of NO_2, SO_2 and PM_{10} on phlegm among women (OR = 1.95 (1.38—2.76), OR = 1.38 (0.97—1.96) and OR = 1.51 (1.06—2.15) respectively).The associations were confirmed when considering exposure in continuous (OR = 1.02 (1.00—1.05), OR = 1.30 (0.16—1.47) and OR = 1.03 (0.98—1.08) respectively).

Lastly, similar odds ratios were found in the sensitivity analysis taking into account long-term exposure (up to 3

Table 2 Association between respiratory outcomes and concentrations of proximity air pollution calculated by dispersion model at the address of the individual.

$N = 2104$	PM_{10}	NO_2	SO_2	Benzene	VOCs	CO
Past year						
Breathlessness	1.30 (0.72; 2.34)	1.44 (0.79; 2.62)	1.64 (0.91; 2.96)	0.71 (0.35; 1.43)	0.70 (0.34; 1.41)	1.04 (0.55; 1.95)
Wheeze	1.02 (0.68; 1.52)	0.82 (0.60; 1.11)	1.15 (0.76; 1.73)	0.55 (0.34; 1.01)	0.65 (0.40; 1.03)	0.78 (0.50; 1.21)
Usual						
Dyspnoea	0.85 (0.64; 1.14)	0.58 (0.64; 1.12)	0.78 (0.57; 1.06)	0.77 (0.57; 1.04)	0.66 (0.48; 1.00)	0.81 (0.60; 1.09)
Cough	1.33 (1.00; 1.77)*	1.30 (0.96; 1.75)	1.55 (1.16; 2.08)*	0.78 (0.56; 1.09)	0.81 (0.58; 1.11)	0.95 (0.70; 1.30)
Phlegm	1.09 (0.79; 1.52)	1.11 (0.79; 1.57)	1.45 (1.04; 2.01)*	0.85 (0.59; 1.22)	0.80 (0.55; 1.15)	0.94 (0.66; 1.33)
Chronic						
Asthma	0.95 (0.66; 1.35)	0.92 (0.63; 1.34)	1.04 (0.72; 1.51)	0.72 (0.48; 1.07)	0.79 (0.53; 1.16)	0.86 (0.59; 1.26)

Values are odds ratios (OR) and 95% confidence interval (95% CI) obtained with the binary logistic regression model adjusted for age, sex, smoking, income of household, level of education, occupation, body mass index (BMI) and heart failure.
Exposure was defined with respect to the third quartile value of the distribution of the evaluated concentrations at home.
*$P < 0.05$.

years) to proximity air pollution although the statistical significance was diminished due to the reduced sample sizes. Exposure to high levels of PM_{10} was associated with usual cough (OR: 1.26 (0.95–1.67)) and that to high levels of SO_2 with usual cough and phlegm (OR = 1.28 (0.96–1.71) and 1.26 (0.90–1.77) respectively).

Discussion

Our assessment of exposure to proximity air pollution has shown an increased prevalence of bronchitis-like symptoms namely usual cough, sputum and shortness of breath in elderly living in areas polluted by SO_2 and PM_{10}.

Previous findings have shown short-term effects of urban air pollution on cardio-respiratory morbidity and mortality in elderly[15–18] but scarce data exist on long-term effects.

In order to understand long-term effects of air pollution, Hoek et al. investigated a random sample of 5000 people from the full cohort of the NLCS study (age 55–69 years) from 1986 to 1994 in the Netherlands.[19] Long-term exposure to traffic-related air pollutants (black smoke and nitrogen dioxide) estimated using background concentrations and an indicator variable of living near major roads were statistically significantly associated between BS, NO_2 and cardiopulmonary mortality with relative risks of 1.71 (95% CI 1.10–2.67) and 1.81 (95% CI 0.98–3.34), respectively. Values were calculated for concentration changes from the 5th to the 95th percentile. For black smoke, this was rounded to 10 $\mu g/m^3$, for NO_2 to 30 $\mu g/m^3$. Using hospital discharge data of 34 USA cities, Zanobetti et al. constructed a cohort of persons discharged alive with chronic obstructive pulmonary disease (COPD) between 1985 and 1999. Persons discharged alive for COPD had a substantial mortality risk associated with exposure to PM_{10}. The risk for mortality for an increase of 10 $\mu g/m^3$ PM_{10} over the previous 4 years was of 1.22 (95% CI: 1.17–1.27).[20] Recently, long-term exposure to higher levels of $PM_{2.5}$ at the residential address was significantly associated with hospitalization for community-acquired pneumonia (odds ratio of 2.26; 95% CI, 1.20–4.24; $P = 0.012$, respectively, over the 5th–95th percentile range increase of exposure) in Canadian elderly which confirms our results.[21] Contrarily to our findings, sulphur dioxide did not appear to have any association (OR, 0.97; 95% CI, 0.59–1.61; $P = 0.918$) in that study.

Most studies on adverse health effects of outdoor air pollution in elderly took into account only background air pollution. With another recent study,[21] we innovated by assessing also exposure to proximity air pollution in elderly people. However, the methods used in these studies were different. In the Canadian study having enrolled from July

Table 3 Association between respiratory outcomes and proximity air pollution by gender.

	Usual cough		Usual phlegm	
	Women	Men	Women	Men
	$N = 1287$	$N = 817$	$N = 1287$	$N = 817$
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
NO_2	1.42 (0.96; 2.10)	1.26 (0.85; 1.84)	1.51 (1.06; 2.15)*	0.81 (0.43; 1.52)
SO_2	1.76 (1.20; 2.58)*	1.54 (1.06; 2.23)*	1.95 (1.38; 2.76)*	1.12 (0.64; 1.95)
PM_{10}	1.29 (0.88; 1.94)	1.39 (0.96; 2.01)	1.38 (0.97; 1.96)	0.90 (0.51; 1.61)

Values are odds ratios (OR) and 95% confidence interval (95% CI) obtained with the binary logistic regression model adjusted for age, smoking, Income of household, level of education, occupation, body mass index (BMI) and heart failure. Exposure was defined with respect to the third quartile value of the distribution of the evaluated concentrations at home.
*$P < 0.05$.

Table 4 Correlation between proximity air pollutants calculated by STREET.

Pearson's correlation	Benzene	VOCs	CO	NO_2	PM_{10}	SO_2
Benzene	1.00	0.99*	0.99*	0.85*	0.86*	0.39*
VOCs		1.00	0.99*	0.87*	0.89*	0.44*
CO			1.00	0.88*	0.90*	0.44*
NO_2				1.00	0.95*	0.52*
PM_{10}					1.00	0.46*
SO_2						1.00

*$P<0.0001$.
VOCs: Volatile Organic Compounds.

2003 to April 2005 345 hospitalized patients aged 65 years or more for community-acquired pneumonia and 494 control participants, also aged 65 years and more, randomly selected from the same community as cases, the annual average levels of nitrogen dioxide, sulphur dioxide, and $PM_{2.5}$ before the study period were estimated at the residential addresses of participants by inverse distance weighting, bicubic splined and land use regression methods and merged with participants' health data. In our study, in the assessment of proximity air pollution we took also meteorological and topographic dimensions able to act on air pollution dispersion into account. Furthermore, the dispersion model allowed estimating the concentration of other pollutants (namely VOC, benzene, CO...).

In the respect of air pollution assessment, the aim of our study was double. First, the study intended to describe exposure to air pollution near to the place of residence of persons aged 65 years and over in a large sample. For the first time, to our knowledge, exposure to traffic-related air pollution at proximity level was estimated in a large sample of elderly. Our data show that levels of background air pollutants were lower than levels of proximity traffic-related air pollutants and hence the need for using proximity measures to better assess health effects of air pollution. Secondly, the study aimed at investigating the relationship between exposure to traffic-related air pollution at proximity and respiratory health of elderly, which had not been done previously. Respiratory health was affected by long-term exposure to particles and sulphur dioxide in our study, two alarming pollutants in towns, especially when the activity of diesel vehicles is high.

Our data support the hypothesis of toxicity of sulphur dioxide also at low levels. In spite of not excessive concentrations of SO_2 at the proximity of the individuals' residence in our investigation, significant relationships were found between this pollutant and bronchitis-like symptoms such as usual cough, sputum and breathlessness. Sulphur dioxide is an irritant gas, particularly for breathing apparatus. However, experimental data do not suggest respiratory effects of SO_2 at low level. Short-term effects of SO_2, including deaths,[19] but no long-term effects have been observed in the elderly. It cannot be excluded that another pollutant of which SO_2 was only a proxy was responsible for the symptoms observed in our study. Furthermore, from the point of view of exposure classification, it must be underlined that exposure to SO_2 was insufficiently assessed in our study where only traffic-related pollutants were estimated. Indeed, SO_2 might be related also to industrial production not taken into account in our model thus underestimating the true association between SO_2 and health.

More consistent was the association found between usual cough and respirable particulate matter in our study. PM_{10} can be inhaled through the upper respiratory airways, and deposited in the lungs thus causing serious respiratory problems and in the long term an increased likelihood of respiratory death.

It has been observed that high peaks of traffic-related air pollution can cause respiratory discomfort in susceptible individuals (asthmatics, young children, elderly...). Furthermore, intense physical exertion increases the effects of air pollutants. This may be even truer among the elderly, especially among those already suffering from a chronic disease. It has been suggested that, in the elderly, the burden of respiratory diseases would depend upon higher intensity and longer duration of exposure to environmental risk factors.[22] However, the elderly are at higher risk of respiratory diseases even after controlling for lifetime active smoking and occupation in our study as well as in previous studies.[22]

Several mechanisms support the hypothesis of a higher frailty to air pollution in elderly. Elderly might be at increased risk of air pollution-related diseases, including respiratory mortality than in the rest of the population because of a larger-than-average exposure to air pollutants not only indoors but also outdoors.[22] Elderly people are likely to spend more time at home and thus to be exposed in excess to indoor pollutants than the rest of the population and thus are more vulnerable to them. Furthermore, due to age-related enhanced breathing during daily life activities (walking, shopping, climbing stairs...) the elderly are likely to inhale more deeply air pollutants. Thereafter, in elderly, even normal activities can increase ventilatory requirements further. This stresses the importance of assessing outdoor air pollution at the proximity of the residence of participants implemented in our study.

In our study, stratification on gender showed that women have a greater risk than men to present cough and sputum in cases of exposure to SO_2 and NO_2, respectively. Our findings support the hypothesis that woman are more susceptible than men to environmental exposures such as tobacco, ETS and air pollution.[23–25] Chronic exposure to PM_{10}, NO_2 and living near a major road increase the risk of developing COPD and can have a detrimental effect on lung function in women.[24] Differences between genders in terms of smoking and exposure to smoke and irritants as well as physiological, biological hormonal and genetic factors, influence women' susceptibility to respiratory diseases.[25] Our data are in favour of a synergetic effect of age and gender. However, other investigations are needed to elucidate it.

Our study has limitations and advantages. The measurement of exposure to outdoors air pollution was limited to a very short period of life of participants. Another important limitation of our study is that we were not able to take into account indoor air pollution as no data were available on indoor exposure in the study 3C. Only, having had an occupation was considered in the analysis. However, the education was included in the model. Lastly, symptoms were reported by the subjects; no verification of the answer has been made. Strong points of our study are that there exist several validations of the questionnaire used and that the population is representative as the subjects were drawn from the electoral rolls. From the point of view of air pollution assessment, wide geographical areas with contrasting air pollution values were covered. Furthermore, levels of traffic-related air pollutants have been stable in these areas in the past decades for PM_{10} and NO_x (www.citepa.fr).

Conclusion

Increasing longevity can determine a rise in medical costs and an increase in the demand for health services, since older people are typically more susceptible to chronic diseases than the rest of the population. Recent data have indicated that the elderly are at greater risk of the effects of outdoor and indoor air pollution because of increased susceptibility and vulnerability.[22] Our results pose additional steps for further research on the effects of outdoor air pollutants in the elderly because they have used for the first time exposure to proximity traffic-related air pollution and related it to bronchitis-like symptoms. Our results were robust as they persisted after adjustment on several confounding factors and the sensitivity analysis taking into account 3-year air pollution.

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Conflict of interest

The authors have declared no conflict of interest.

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